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Description of the previously unknown advertisement call of *Isthmohyla zeteki* (Anura, Hylidae)

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The small treefrog *Isthmohyla zeteki* (Gaige, 1929) is endemic to Costa Rica and Panama, where it inhabits the Premontane and marginally the Lower Montane Zone of the Cordillera Central, Cordillera de Talamanca, and Cordillera de Tabasará (Savage, 2002; Köhler, 2011). Although the species has been known for more than 80 years and is regularly found in suitable habitat only little information on its natural history has been published to date. The species seems to be closely connected with large bromeliads, which normally grow in the canopy region of large trees (Dunn, 1937; Duellman, 2001; Savage, 2002). Thus, like in other canopy dwelling frog species, basic aspects of its life history, such as vocalisations, are still unknown. Only recently, Lindquist and Cossel (2007) succeeded in recording and describing the vocalisations of *Isthmohyla picadoi* (Dunn, 1937), another canopy dwelling species, which seems to be closely related to *I. zeteki* (Duellman, 2001; Faivovich et al., 2005; Savage, 2002). As the advertisement call of anurans is very useful to identify frog species during inventory and monitoring projects (Heyer et al., 1994), its knowledge is especially helpful in canopy dwelling species, as these are more frequently heard than seen.

The following observations were made in a recently discovered population (Köhler et al., 2008), in the very east of the species known distribution range at La Nevera (8.5°N, 81.8°W, 1700 m asl), Serranía de Tabasará, Comarca Ngöbe-Buglé, Panama. On 09 May 2008 at 23:30 hr we observed a male and a gravid female, containing 21 eggs, of *I. zeteki* in a large terrestrial tank bromeliad (Fig. 1) that grew at a cleared roadside. This bromeliad, most likely a *Werauhia ororiensis*, usually grows in the crown of large trees, but also has the ability to thrive terrestrially under appropriate conditions (D. Cáceres pers. comm. 2012). Both individuals of *I. zeteki* were collected and deposited in the herpetology collection of the Senckenberg Research Institute, Frankfurt am Main, Germany (SMF). The male (SMF 94454; snout-vent length (SVL: 23.2 mm) was calling from deeper inside the bromeliad, while the female (SMF 94455; SVL: 26.4 mm) sat on one of the plants outer leaves. We used a Sennheiser ME 66 directional microphone capsule with a Sennheiser K6 powering module in a distance of about 50 cm from the bromeliad on a tripod, and recorded the calling male with the Marantz PMD 620 digital recorder. Calls were recorded in uncompressed PCM format at a sampling rate of 48 kHz with 24 bit resolution, and stored it as a wav-file on SD Card. Relative humidity (RH) while recording was 70% at an air temperature of 17° C and a barometric pressure of 1025 mB. We recorded a section of 05:18 minutes until the male stopped calling. In this time, four complete calls could be obtained. Call editing and analysis were performed using Sound Ruler 0.9.6.0 (Gridi-Papp, 2003–2007) for frequency analysis and to generate figures of oscillograms and audiospectrograms at Hanning window type, 1024 FFT length and an overlap of 0.9 between FFTs. We measured temporal parameters manually, using Adobe Audition 3.0. All measurements are given as range, followed by mean±SD in parentheses. We follow Duellman and Trueb (1986) in call terminology.

A visualisation of a characteristic call is given in Fig. 2. An overview of the measured call parameters is given in Table 1. The call duration is 3.9–4.1 s (3.99±0.09) with inter-call intervals of 92–97 s (95.8±2.6). Each of the four recorded calls consists of five notes, all of which are pulsed. There is no evident frequency modulation and, the dominant frequency of notes does not vary noticeable throughout the call, but notes differ from each other in several parameters. The first note (Fig. 2B) differs from the following ones in having a harmonic structure, and in having a high number of pulses, as well as a high pulse rate. The following two notes, namely

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Figure 1. Large tank bromeliad (most likely *Werauhia ororiensis*) with a flowering orchid (*Otoglossum chiriquense*) in the front, growing on ground soil at a cleared roadside at La Nevera, Serranía de Tabasará, Comarca Ngöbe-Buglé, Panama.

second and third (Fig. 2C,D), are much shorter than the others and consist of only four to six pulses. In contrast, the last two notes (Fig. 2E,F) are almost double as long as the first note, whereas pulse rate is much lower. In general, pulse rate decelerates from the first towards the last note, although the last note is on average slightly longer than the penultimate one.

Comparing the advertisement call of *I. zeteki* with the data of Lindquist and Cossel (2007) for the advertisement call of *I. picadoi,* a similarity of the general composition of the call can be observed, although many differences in spectral and temporal parameters are evident, making calls of the two species readily distinguishable. In general, the body size of a frog is negatively correlated with the frequency of its call (Gerhardt and Huber, 2002). Consequentially, the dominant frequency in the call emitted by the smaller *I. zeteki* (23.2 mm SVL in the recorded male) is more than 1000 Hz higher compared to the call of the larger *I. picadoi* (27–32 mm SVL; measurements according to Savage 2002). Moreover, total duration of a typical call produced by the latter species is on average about 2 s longer. The advertisement calls of both species are initiated by a strongly pulsed note, followed by a series of notes with less pulses and lower pulse rates. However, while in *I. picadoi* the initial note is followed by a series of single, double or triple pulsed notes, none of the notes in *I. zeteki* has less than four notes in our analysis. Lindquist and Cossel (2007) reported on short calls in *I. picadoi* lacking the initial note, an observation that we could not confirm for *I. zeteki* so far.

This preliminary comparison of advertisement calls, confirms the apparent close relationship of *I. picadoi* and *I. zeteki* once more, that was so far only supposed on the basis of morphological characters (Duellman, 2001; Savage, 2002; Faivovich, 2005). Now that calls of both species are known, the advertisement call characteristics in combination with adult and larval morphological characters, and bromeliad-dwelling life history support the view of Savage and Heyer (1969), Duellman (2001), and Savage (2002) of a "*Hyla*" *zeteki* group, apart from other Middle American hylids, contrary to the presently recognized *Isthmohyla pictipes* group of Faivovich et al. (2005).

Faivovich et al. (2005) formed this group out of the members of the former *Hyla zeteki*, *H. lancasteri*, *H.*

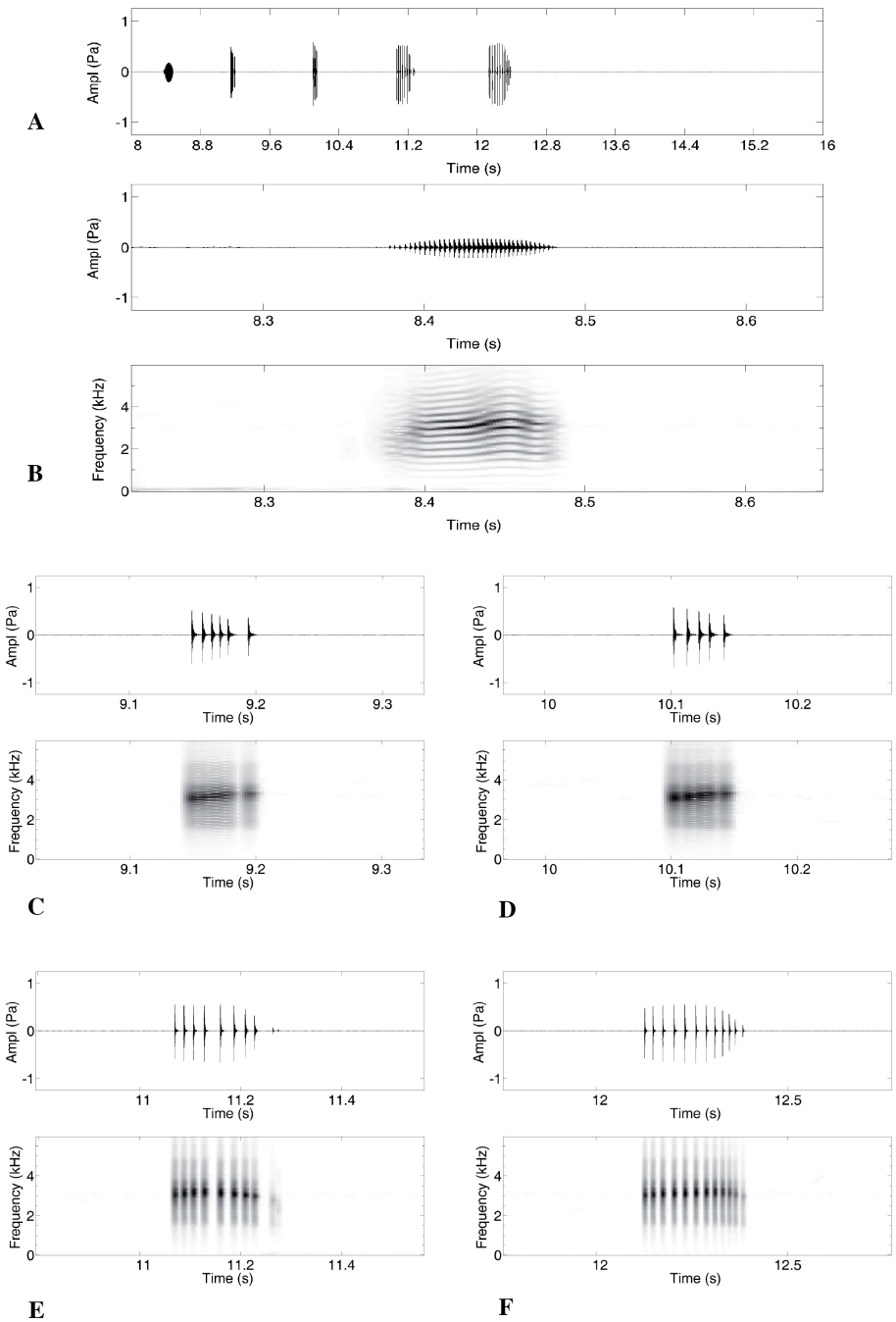

Figure 2. Visualisation of a characteristic call of the male *Isthmohyla zeteki* (SMF 94454). Figures created at Hanning window type, 1024 FFT length and an overlap of 0.9 between FFTs. **A.** Oscillogram of a complete call. **B.** Oscillogram and audiospectrogram of first note. **C.** Oscillogram and audiospectrogram of second note. **D.** Oscillogram and audiospectrogram of third note. **E.** Oscillogram and audiospectrograms of fourth note. **F.** Oscillogram and audiospectrogram of fifth note.

Table 1. Characteristics of the advertisement call of a male *Isthmohyla zeteki* (SMF 94454), subdivided into the separated notes. Range (mean±SD). Recorded in situ under conditions as detailed in text.

Character	Note 1	Note 2	Note 3	Note 4	Note 5
Note length (s)	0.098–0.121	0.036–0.05	0.035–0.045	0.166–0.215	0.239–0.267
	(0.109±0.01)	(0.041±0.01)	(0.040±0.00)	(0.192±0.02)	(0.258±0.01)
Number of pulses	34–36	5–6	4–5	8–12	11–17
	(35±1.15)	(5.5±0.58)	(4.5±0.58)	(9.5±1.91)	(13±2.71)
Pulse rate (pulses/s)	297.5–346.9	115.3–153.8	105.3–116.3	44.4–55.8	45.5–63.7
	(323.4±25.11)	(134.9±16.00)	(111.8±4.80)	(49.2±4.76)	(50.3±8.94)
Min. frequency	3070–3490	3120–3350	3120–3350	3070–3350	3070–3310
(Hz)	(3280±127)	(3230±76)	(3230±88)	(3210±90)	(3200±79)
Max. frequency	3070–3490	3160–3350	3120–3350	3070–3350	3070–3350
(Hz)	(3300±124)	(3270±66)	(3280±79)	(3220±89)	(3220±83)
Dom. frequency	3070–3490	3120±3350	3120–3350	3070–3350	3070–3300
(Hz)	(3290±126)	(3240±75)	(3260±79)	(3320±88)	(3200±80)
Fund. frequency	341–388	350–370	350–370	340–370	340–370
(Hz)	(360±14)	(360±8)	(360±9)	(360±10)	(360±9)

pictipes, and *H. rivularis* groups of Duellman (2001), based on the inclusion of only a single specimen of *Isthmohyla rivularis* in the molecular analysis. Therefore they were not able to test its monophyly. For all ten species in the *I. pictipes* group, but for *I. xanthosticta*, are descriptions of vocalizations available now. Looking at bioacoustic similarities in the groups defined by Duellman (2001), and leaving interspecific differences aside, all species in the former *H. rivularis* group call in a series of short, high pitched, cricket like notes (Duellman, 2001; Savage, 2002), while the call of *H. pictipes*, the only species in the former *H. pictipes* group, consists of a single low-pitched note (Duellman, 2001; Savage, 2002), and the species in the former *H. lancasteri* group produce a low-pitched call consisting of usually one, occasionally two or three, rattling notes (Lips, 1996; Savage, 2002).

Future, integrative studies will have to clarify the phylogeny of these groups, and even of the whole genus *Isthmohyla*, which, as currently understood, besides the *I. pictipes* group also includes the *I. pseudopuma* group.

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